Chapter 6
Transforming Our Society: Low Carbon, Coexistence with Nature, and Sound Material Cycle

6.1 Earth History, Human History

6.1.1 An Instant in Time

When our human ancestors still lived only in Africa, the population was apparently only about 100,000. This figure is estimated from current numbers of chimpanzees and other anthropoid apes. Ten thousand years ago, when the Earth began to warm up at the end of the last Ice Age, humans adapted to the changing global environment and began to engage in settled cultivation. Five thousand to six thousand years before the present day, humans began to live together in settlements and urban civilizations developed in the basins of the Nile and Yellow Rivers. In ancient Egypt and the Xia, Yin, and Shang dynasties in China, populations grew to a few million people, and the world's total human population is estimated to have exceeded ten million. At their peaks about 2000 years ago, the populations of the Roman Empire [1] and the Han Empire both exceeded 50 million, and the estimated total world population was 200–300 million, including large populations in what are now India and Mexico. The human population first exceeded one billion in about 1800. In 2012, our population exceeded seven billion.

Humans dominate the Earth today. But it was only 250 years ago, after the Industrial Revolution, that we were first able to exert such control through our science and technology. A scant 10,000 years have passed since humans first began settled cultivation. Will the modern civilization that we currently take for granted turn out to be nothing but the momentary blossoming of a flower in the long history of the Earth?

6.1.2 Economy and Ecology

In recent years, the term "eco" has come into common use as an alternative for "environment." Its recent use comes from the English word "ecology." "Economics"

H. Imura, *Environmental Systems Studies: A Macroscope for Understanding and Operating Spaceship Earth*, DOI 10.1007/978-4-431-54126-4_6, © Springer Japan 2013

also begins with the same “eco.” The origin of “eco” is the ancient Greek word *oikos*, which originally meant household, house, or family. How could it be that both “economy” and “ecology” come from the same roots?

Modern society has corporations and a great variety of other organizational structures, but in ancient Greece, where farming and raising livestock were the core productive activities, the *oikos* (family) was the basic unit of society. Families had a master, family members, and slaves, and possessed a certain amount of farmland and grazing land. They were almost completely self-sufficient, running on solar energy [2]. The size of the grain harvest and number of animals were determined by factors such as the amount of land owned, amount of sunshine, temperature, and rainfall.

Imagining the situation of families in ancient Greece, we can understand now how both economy and ecology can have the same origin. Economy had to do with managing the family on the earnings from farm produce harvested and sold. The word “economics” has similar origins, associated with the home economics of managing the family income and expenditures. On the other hand, “ecology” was concerned with the natural conditions that determined how much income could be earned, including the size of crops to plant and how many livestock to raise.

6.1.3 Closed Economy, Open Economy

An economy based on agriculture and livestock and mostly affected by the blessings of the heavens and earth is what economist Kenneth E. Boulding referred to as a closed economy [3]. This is an economy that operates within relatively small regional confines and does not engage in much interregional trade. In ancient Greece, all necessities—clothing, food, housing, etc.—were obtained from the harvests from nature, and all waste had to return to nature. During that era, economy and ecology were basically the same thing.

The separation of the two “ecos” came with the birth of the modern industrial civilization, as a result of the Industrial Revolution at the end of the eighteenth century. Motive power before the Industrial Revolution came from human and animal power. The fastest transport was the speed of a horse running. After the Industrial Revolution, humanity had at its disposal unprecedented power and speed, through the use of steam engines and, eventually, internal combustion engines. As a result, humanity was able to excavate and exploit on a vast scale buried resources such as fossil fuels, metals, and minerals, and to use them as if their supply was endless. This was the beginning of the “open economy,” or cowboy economy, as Boulding called it. Eventually, huge amounts of commodities could be carried enormous distances, by rail, ship, automobile, or airplane.

It was fossil fuels that sustained the Industrial Revolution. About 100 years after the start of the Industrial Revolution in England—by the end of the nineteenth century—steel was being used abundantly in Europe and America. In 1853, an American navy fleet, known in Japan as the Kurobune, or Black Ships, appeared

offshore of Edo and eventually compelled Japan to open to the West. Those ships were clad in iron, making them appear black. The first transcontinental railroad opened in 1869 in the United States, and the Eiffel Tower, with its monumental structure made of iron, was completed in 1889 for the World Exposition in Paris. In Europe, at the end of the nineteenth century, architecture and decorative art often used iron as a material for what was known as Art Nouveau. The First World War was a conflict that consumed huge amounts of iron in guns, canons, cannonballs and warships.

The model of industrialization based on coal and iron is still alive and well today in the twenty-first century. China is a good example of this. After the Second World War, China experimented with nation building under a communist regime using socialism. The philosophy of Mao Tse-tung put an emphasis on agriculture, farmers, and farm villages, and in the sense that he attempted to achieve economic development by using only resources within the country rather than depending on the outside. His philosophy was one of a closed economy. This experiment failed, however, and from 1979 onward under the leadership of Deng Xiaoping, the country shifted toward an open policy. In terms of economic openness, China also moved toward an open economy in terms of resource use. The consumption of coal and iron increased rapidly. Annual iron production in China during the 1950s was about five million tons. By 2007, production had risen to 2.6 billion tons of coal and 500 million tons of iron. In a way, this all makes sense if we realize that China is now achieving its own delayed Industrial Revolution.

6.1.4 Agricultural Civilization

Archaeologists have made many interesting discoveries about where and when agriculture first began. It is said that the cultivation of wheat and barley began about 9000 BC in the region around present-day Palestine. This cultivation was propagated to Egypt and Mesopotamia, where large-scale irrigated farming began in the river basins of the Nile, Tigris, and Euphrates. There are several theories about the exact timing, but it seems that this likely occurred about 5000 BC. Agriculture also began along the Yellow River and Yangtze River in China. Evidence suggests that wheat cultivation arrived in northern China from Mesopotamia via Central Asia, whereas rice cultivation came to southern China via a different route.

Large-scale irrigated agriculture made it possible to produce and store large amounts of grain. Agriculture produced large surpluses, which freed people from having to dedicate their days completely to obtaining food and allowed them to produce goods such as pottery and bronze, and this led to the building of civilizations. It is possible that climate change after the end of the last Ice Age caused the extinction of the animals that humans hunted, so they ceased their nomadic roaming and had to cope with the new problem of securing food. It is also possible that under the new environmental conditions, humans discovered wild grains, millet, and leguminous plants, and began to cultivate them. In Japan, traces have been found at the

Sannai-Maruyama site in Aomori Prefecture indicating that the people cultivated chestnut trees during the Jomon period. Discoveries such as these have been made through research into pollen buried in ancient ground layers.

The conversion of grasslands to cultivated land and the creation of water courses for irrigation marked the beginning of human activities that alter and manage nature. It has never exactly been easy, however, for humans to manage nature. The water that was so essential for agriculture was controlled by natural conditions such as sunshine and precipitation. Lack of rain would mean a drought; too much rain, however, the fields would be washed away by flooding.

If irrigated farming continues for long, ground salt dissolves in the water and then is deposited on the ground surface. In a country of abundant rainfall such as Japan, the salt is washed away by the rain, but in arid regions like Central Asia, it gradually builds up on the ground surface, eventually making the land unsuitable for agriculture: this is referred to as salinization of soil. One theory suggests that the ancient Mesopotamian and Indus Valley civilizations collapsed as a result of soil salinization, which was caused by irrigated farming over many years.

The productivity of an agricultural civilization is strongly influenced by the area of land that can be used as farmland and by the productivity of the land. And land productivity is determined by such factors as the nutrients in the soil, natural conditions such as hours of sunlight and amount of precipitation, the use of farm implements such as hoes and harrows, irrigation infrastructure, and farming methods. In any case, because agriculture was the source of production, the crop sizes were largely affected by climate conditions. This situation is exactly the same as for agriculture nowadays [4]. Today, however, recombinant DNA technology makes it possible to use selectively pest-resistant and climate-resilient crops that produce high yields.

6.1.5 Links Between Climate and the Industrial Revolution

During the Medieval Warm Period, the Vikings of Scandinavia became active and discovered Greenland and the American continent. The cooling of the climate during the Little Ice Age was a huge blow to agriculture. Also, in China and surrounding areas, climate change forced northern nomads to descend southward in response to a lack of feed grass for their animals, and this had a major impact on Chinese history and dynastic change.

There is an argument that the cooler climate of the modern Little Ice Age was a trigger for the Industrial Revolution. In England and other European countries, wood fuel was needed for warmth in the cooler climate conditions, which led to the clearing of their forests. Thus, to find a replacement for firewood, it was necessary to dig for coal, and this led to the invention of the steam locomotive, which was used to remove water in coal mines as well as to transport the coal to industrial sites.

So cooling may have brought on the Industrial Revolution, and the massive use of fossil fuels has brought on global warming. There is a profound connection between climate and history. The three great civilizations of Egypt, Mesopotamia,

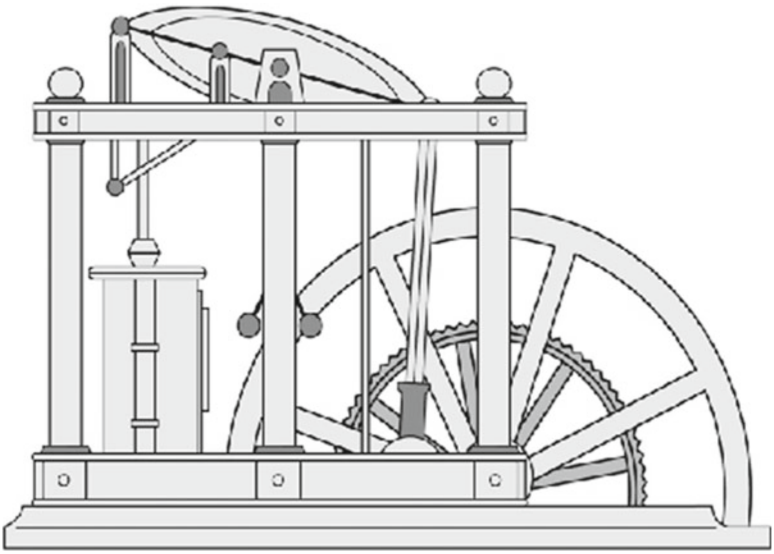

Fig. 6.1 A Wattsteam engine
Note: The steam engine fuelled primarily by coal propelled the Industrial Revolution in Britain and the around world. *Source*: Provided by Kagaku-dojin Publisher

and China were the products of climate change. All together, the global ecosystem and the human activities that depend on it make up one interactive system. Climate warming and cooling, and the changes attendant in the climate such as changes in precipitation, aridity, and humidity—these have had huge impacts on human activities. To adapt to climate conditions, humans changed their lifestyles and societal systems and developed technologies. The very history of humanity—the social disruptions, human migrations, wars, and so on—is a product of repeated cycles of climate processes over hundreds, thousands, and tens of thousands of years [4].

6.1.6 The Industrial Revolution and Modern Industrial Civilization

Modern industrial civilization emerged at the end of the eighteenth century, with the Industrial Revolution in England. The deciding factor here was James Watt's improvement of the steam engine in 1785. A prototype steam engine had already existed, but it was Watt who succeeded in converting the steam engine's energy from piston motion to rotational motion (Fig. 6.1). This was the birth of the reciprocating steam engine.

The steam engine brought about dramatic changes in human society. It was used to pump water out of coal mines, which helped to dramatically increase coal production. Railways were created, and the speed and carrying capacity of transportation jumped significantly. Coal provided the power for steam engines, and the railways made of iron made it possible to carry the mined coal great distances.

Fig. 6.2 The Ford model T
Note: In 1908, Ford Motor Company produced the first affordable automobile. Since then, automobiles have been a symbol of the prosperity of high-carbon society. Today, a hundred years later, automobile industries in the United States and around the world are facing a challenge. What comes next in the age of transition to a low carbon society. *Source of picture*: http://en.wikipedia.org/wiki/Ford_Model_T

The steam engine was also used in textile machines, which led to mass production of cotton yarn and the expansion of the cotton spinning industry.

Besides the steam engine, another important development early in the eighteenth century was a new iron-making process that used coke. Until then, wood charcoal was used in iron making, but that method required the large-scale logging of forests. At the time, England was suffering from a severe shortage of timber because forests had been cut down for fuel, which resulted in serious problems for iron production. Thanks to the steam engine and the use of coke in the steel-making process, iron could be mass produced, and this made it possible to manufacture machines and ships and other things from iron, and also made possible the construction of railroads.

Steam engines also had an enormous impact on the development of cities. Until then, factories were built along rivers to allow the use of water power, but the steam engine made it possible to construct factories in the suburbs away from rivers. The result was that emerging commercial and industrial cities such as Manchester and Glasgow experienced further growth.

The emergence of the key technology of the steam engine caused enormous changes in the economy, society, and even in politics. After the reciprocating steam engine came the steam turbine and other technological innovations such as the internal combustion engine that used petroleum-based fuel, but the basic framework of civilization born of the steam engine and coal has essentially remained unchanged. This is a civilization constructed on fossil fuels such as coal and oil—the "fossil fuel civilization." In this sense, this is also a "high-carbon society," and its manifestation is the automobile (Fig. 6.2).

Incidentally, China and Japan also had iron-making processes based on wood charcoal. Japanese writer and historian Ryotaro Shiba theorized that the reason China lost its forests was logging for production of iron over its long history. In ancient Japan, a group by the name of "Tatarashi" made iron in the mountains of the Chugoku district of the country. In the legend of the *Yamata no Orochi* (a mythical eight-headed serpent), red blood poured from the beast and the story tells that a sword was discovered in its body. One interpretation is that there was an iron-making group in the mountains, that it cut many trees, and that heavy rains caused a washout of reddish soil.

6.1.7 A New Civilization: Low-Carbon Societies

The emergence of global warming as an issue clearly shows us the limits of the fossil fuel civilization. Today humanity is beginning to search for ways to become a civilization based on technological systems that do not depend on fossil fuels. It is of historic significance that the term "low-carbon society" has come into common use recently. So now we must ask: exactly what is a low-carbon society? Simply stated, it is a society that uses the least possible amount of fossil fuels such as oil and coal. The ideal would be a society that does not use fossil fuels at all—a "decarbonized society" or a "carbon-free society."

If it was the appearance of the steam engine that brought about the modern industrial civilization—that is, the fossil fuel civilization—what technology holds the key to a low-carbon society? Can nuclear power replace fossil fuels as a source of energy? Or can renewable energy such as solar energy or biofuels do the job? Or will it perhaps be innovative technology such as nuclear fusion? Based on the progress in science and technology that we have witnessed in our own lifetime, and reflecting back upon the major socioeconomic changes we have experienced, we cannot help but feel that it is extremely difficult to predict the future. The capacity of the large computer we first began to use in about 1970 is no comparison to one of today's personal computers. It was beyond imagination that the Internet would spread as far and wide as it has. On the other hand, some technologies such as power generation from nuclear fusion have not made the progress people had expected or hoped would occur.

If nuclear power or some other future development of fusion power can replace fossil fuels, humanity may be released from energy constraints. But will the scenario be desirable for spaceship Earth? After being released from one constraint, it is likely we will crash into another. History is an endless repetition of this kind of endeavor, and there are no final answers.

6.2 Aiming for Sustainability

6.2.1 What Is Sustainability?

The principle of "sustainable development" was presented as a core concept at the Earth Summit in 1992, but what exactly is it? By way of background, it was the

World Commission on Environment and Development (WCED), established by the United Nations, that made the preparations for the Earth Summit. The commission's final report, issued in 1987 and titled "Our Common Future," was the first place this principle appeared [5, 6]. It defines sustainable development as development that "meets the needs of the present without sacrificing the ability of future generations to meet their own needs." At first glance this may not seem to be the easiest concept to grasp.

Recent debate about pension systems in Japan gives some good material to consider what sustainability really is. Pension systems are designed to maintain sustainability by having the younger working generation bear the burden of paying for the system, but as a result of the trend to lower birthrates and aging of society in Japan, there are now relatively fewer young people, and eventually the system could collapse. Increasing the size of the government's fiscal deficit as an economic strategy is another way to transfer economic burdens to the future. Indeed, deficit financing by government is public spending to meet the "needs of the present generation." An excessively heavy burden placed on future generations may render them unable to meet their own needs.

Economist Herman Daly proposed three precepts for the sustainable use of resources, the gist of which can be summarized as follows: (1) the rate of use of "renewable resources" (forests, fisheries resources, etc.) must not exceed the ability of the ecosystem to regenerate the resources; (2) the use of "nonrenewable resources" (fossil fuels, minerals, etc.) must be at a pace that does not exceed the rate of development of renewable substitutes; and (3) the emissions of pollutants must not exceed nature's self-cleaning capacity (or environmental space) [7]. The second principle here may be slightly difficult to grasp, but if we take the example of oil, anticipating the fact that oil will be depleted in the future, we should take a portion of the profits from the use of oil and invest it into the development of renewable natural energy to compensate for the depletion of the finite resources.

As for the sustainability of natural resources, there is a famous argument about the substitutability between "natural capital" (as in an old-growth forest) and "manmade capital" (as in a plantation forest). There is a stance that the natural capital has its intrinsic value that cannot be substituted by manmade capital, and we must strictly maintain the renewal capacity of the natural capital. There is another stance that if the function is the same, it is acceptable to substitute manmade capital for natural capital. The former is valued as "strong sustainability" and the latter as "weak sustainability."

6.2.2 Waves and Cycles in the Environment and Economy

We seem to believe that it is entirely normal to expect an economy to always continue growing, but can we really expect that to happen? During this century the world population is generally expected to continue increasing, but if the world population started to actually decrease, what would be the implications for the economy?

It is well known that the economy moves in waves, but it is important to also realize that economic waves greatly affect the general level of interest in environmental problems, the willingness to tackle them, and the size of investments in the environment. A growing economy means rising consumption of energy and resources, and also a steadily growing burden on the environment, but a growing economy also boosts investment in research and development, and facilitates progress in efforts to seek harmony between the environment and human activities. Conversely, during a recession, the consumption of both resources and energy drops, and overall investment into research and development also tends to drop.

In our experience of the past 50 years or so, there have been several waves in the environment and economy. During the period of rapid economic growth from the 1960s through to the oil shock of 1973, Japan experienced many problems with industrial pollution, but it also turned into a period of large investment into pollution prevention. The 1980s were rather like a winter for domestic environmental policy in this country. Nevertheless, at the international level, the issue of global warming was taken up seriously, and along with the end of the Cold War between the East and West, and the expansion of the European Union eastward, the international community made some progress in environmental policies, with Europe leading the way. During the 1990s, even though Japan suffered from the after-effects of its burst economic bubble, it still made considerable progress in environmental policies, spurred on by an international tailwind.

6.2.3 The Drivers of Progress

Various global economy and technology scenarios have been developed to help predict future global warming, but not one of them includes a scenario for an extended period of negative growth for the global economy [8]. This seems somewhat strange. The basis for economic forecasting is our experience of, at the most, the past 100 years or so. There have been anomalies in history, such as Great Depression that started in 1929 and the Second World War from 1939 to 1945, but the general assumption has been that human society will continually move in the direction of progress, expansion, and development. Actually, however these things are not guaranteed.

The real driver of human progress is the power of science and technology, and the source of this power is none other than human creativity. New inventions, discoveries, and technological developments have created new products, promoted human health, and extended human life through advances in medicine [9]. For sustainable development from now on, the key issue is whether we can develop and spread technologies that will contribute to both environmental improvements and economic growth. In 2008, Barack Obama, as newly elected President of the United States, announced initiatives that would create much employment through investment in areas such as improving buildings to boost energy efficiency; expansion of public transport and rail freight; development of advanced power grid systems; wind power, solar power; advanced biofuels, and so on.

The macroeconomic model of economic growth tells us that by diverting a portion of current production to invest for the future it is possible to increase future production capacity, and we are told that this facilitates sustainable economic growth. If the economy falls into a recession, however, the private sector has fewer funds to invest, so the role of governments becomes more important.

Aiming for economic revitalization during the 1980s when the economy was in recession, the United Kingdom's Prime Minister Margaret Thatcher and United States' President Ronald Reagan were among the leaders promoting neoliberalism with its focus on the role of private sector activity. As this book is being written in early 2009, those two countries are both embracing policies that enlarge the role of government. This step is made necessary by circumstances, although many people are concerned about growing fiscal deficits. With combined national and local government fiscal deficits of more than 800 trillion yen, or 1.6 times gross domestic product, Japan too is in a serious situation today. In this context, we are being tested as to whether or not we can read the trends and make the right economic and environmental decisions.

6.2.4 Societies with Sound Material Cycle

On the surface, the "metabolic" mechanisms of input and transformation of resources and energy associated with human activities seem to resemble what happens in natural ecosystems. Humans live by eating food every day, digesting it, and excreting the waste, and the natural world contains ecosystems that completely recycle this waste. Sustainable systems incorporate mechanisms to maintain this kind of steady state. The natural world has perfect recycling systems based on metabolic mechanisms. In contrast, our modern industrial civilization is built upon the mass consumption of buried resources such as fossil fuels and minerals. The products produced are difficult to dispose, and some of them become hazardous waste that accumulates in the environment. This scene is very different from recycling in the natural world.

The field of "industrial ecology" has appeared as a discipline that analyzes the material flows generated artificially from human activities in modern industrial societies. Since about 1980, experts have been attempting to redesign the material circulation systems of our modern industrial civilization based on lessons from the natural world. Related concepts included reducing resource inputs and environmental pollutant generation to the smallest possible levels per unit of production, and these measures led to the concepts of "eco-efficiency," "factor four" (doubling wealth, halving resource use), and "zero emissions" [9–12]. The concept of "sound material-cycle society" (or a "recycling-based society," in Japanese *junkangata shakai*) was born in response to the serious issue of trying to stop the constantly growing volume of waste in society. Japan even passed the "Basic Law for Establishing a Sound Material-Cycle Society" into law in 2000.

We must not forget, however, that large differences still exist between the material cycle of the natural or biological world and the materials cycle in modern

industrial society. The former is powered by solar energy and is based upon plant photosynthesis and circulation in the food chain, the latter upon fossil fuels and nuclear power. Many industrial products contain a variety of regular and rare metals as well as persistent chemicals, which when left in the environment can become substances hazardous to ecosystems. In contrast, “manufacturing” in the natural world was self-organizing through the long processes of evolution, so anything created that has finished its purpose is decomposed again naturally, and nothing toxic remains.

During this century, manufacturing technology will change dramatically. One day, we will probably be able to recycle and reuse most of the existing aboveground stock of metals, and we will probably be able to create high-performance materials using biotechnology. It may be also possible that computers will use biochips or neural circuits instead of today’s solid state integrated circuit chips. The key to success may be the improved understanding of and learning from the miraculous functions of living things and ecosystems, and the development of technologies that mimic them.

6.2.5 Social and Economic Paradigm Shifts: Dematerialization, Less Ownership, More “Servicizing”

The concept of “sound material cycle” originated in Germany in the 1990s from the concept of “Extended Producer Responsibility” [13]. People thought it was unacceptable for municipal governments to bear all the responsibility of collecting and disposing of household waste. The manufacturers and retail stores that made or sold the products that ended up as waste should bear some responsibility. This concept was quickly embraced in Japan, which quickly enacted the legislation for a sound material-cycle society.

A fundamental shift in thinking is still needed to incorporate the concept of extended producer responsibility into the economic system that we will simply take for granted.

Today when we purchase a product, we take ownership of that item, and when we are finished with it, the used product becomes waste. But if the manufacturer were to take the item back again, the ownership would revert back to the manufacturer. In such a scenario, it would be more sensible to *lease* the item instead of *purchasing* it. In that case, the ownership would stay with the manufacturer throughout, and the user would enter into a leasing contract with the manufacturer. This is already exactly how we expect things to happen with a rental apartment or an office.

Let us consider how this would work with an automobile. What is the reason that we purchase a car? Do we own cars as status symbols? Or are they for the purpose of transport? Even if you own a luxury import car, what is the point in owning it if you have little opportunity to drive and it stays parked most of the time? If the car is only driven occasionally, it would be much cheaper to rent a nice car only when needed.

Property and consumer durables (e.g., houses, automobiles, household appliances) have both ownership value and "usership" (or service) value. Societies in the future may place more importance on the value of use, or the value of service that the item can provide rather than on ownership. Ultimately the outcome is decided by consumer preferences, but people could choose to lease or rent the car of their choice just when they need to use it. This attitude could be a way for society to achieve a major transformation toward "servicizing," shifting away from ownership and instead placing value on the services they can obtain from things.

6.2.6 Transition Toward a Low-Carbon Society

Technological progress since the Industrial Revolution has been remarkable, but it is fossil fuels that were the driving force behind economic growth. Fossil fuels made possible the production of great amounts of iron, and as a raw material iron made it possible to build tall buildings, ships, automobiles, and other many items. Almost all forms of transport—automobiles, ships, aircraft, and others—depend on fossil fuels and internal combustion engines for motive power.

A low-carbon society is one that has shifted away from its dependence on fossil fuels. Expanded use of nuclear power might be one way to follow this path, but it comes with safety concerns, and there are also risks such as the proliferation of nuclear weapons and terrorism in politically unstable countries or regions. Within Japan, the natural energy that can be used anywhere is solar energy. It may be difficult to have solar replace all uses of fuels, but in small and medium cities with good climatic conditions, it is possible to use solar to meet almost all noncommercial energy demand, such as for heating and cooling.

The automobile was a phenomenon of the fossil fuel civilization, which is a high-carbon society. Diverting biofuels to automobile use sets up competition for agricultural resources between production for food and production for fuel, so there are quantitative constraints on the use of biofuels as a solution. Today, Brazil and the United States show great potential for biofuel production, and there are concerns that biofuels could be the next strategic commodity after oil. Ultimately, however, we must redesign our cities and transport systems to allow us to live without depending on the automobile.

During the first half of this century, economic growth will continue in countries with large populations such as China, India, and Brazil. Some are strongly concerned about the pressures of resource demand in these countries. The above-the-ground stock of iron in industrialized countries exceeds 10 tons per capita, but in China it is still only about 2 tons per capita. Even if that country's annual production of 685 million tons in 2011 was an anomaly, iron is still needed in China, so production is likely to continue until aboveground stocks reach at least two or three times the current level.

The foregoing may seem relatively pessimistic, but there is also hope. Japan is already experiencing low birthrates and the aging of society. There is a big chance that population growth rates in developing countries will be below current projections.

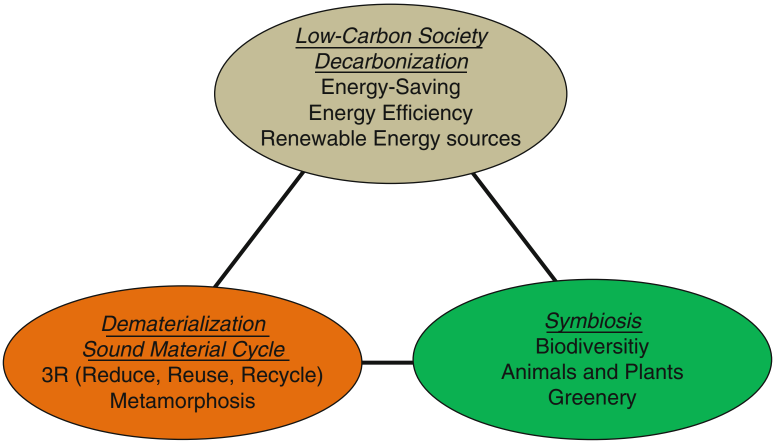

Fig. 6.3 Triple goals of sustainability in the twenty-first century

If world population growth rate slows after the middle of this century, the pressure on the environment will quickly decline. What Japan is experiencing now is already proof of that. Basic commodities such as iron are already being recycled extensively, so the amount of new production from raw materials (or virgin resources) can be expected to drop dramatically in the future.

Biotechnology holds much promise as a core technology for a low-carbon society, but for that to happen, it is essential that biodiversity be preserved. Biotechnology is likely to be a critical technology, whether it be for food, biofuels, chemicals, pharmaceuticals, or environmental remediation. In the end, we must aim simultaneously for three goals: a low-carbon society, coexistence with nature, and sound material cycle (Fig. 6.3).

References

1. Harl K W (2012) Population estimates of the Roman empire. http://www.tulane.edu/~august/H303/handouts/Population.htm. Accessed date: December 8, 2012
2. Odum HT (1971) Environment, power, and society. Wiley-Interscience, New York
3. Boulding K (1966) The economics of the coming spaceship earth. http://dieoff.org/page160.htm. Accessed date: December 8, 2012
4. Fagan B (2006) The great warming: climate change and the rise and fall of civilizations. Bloomsbury, New York
5. World Commission on Environment and Development (1987) Our common future. Oxford University Press, Oxford
6. Blewitt J (2008) Understanding sustainable development. Earthscan, London
7. Daly HE (1990) Toward some operational principles of sustainable development. Ecol Econ 2:1–6
8. Stern N (2006) Stern review on the economics of climate change. HM Treasury, London
9. Scumpeter JA (2011) A theory of social and economic evolution. Palgrave, Basingstoke

10. Von Weizsacker EU, Lovins A, Lovins H (1995) Factor four: doubling wealth, halving resource use—a report to the club of Rome. Earthscan, London
11. Schmidt-Bleek F (2008) Factor 10: the future of stuff. Sustain Sci Pract Policy 4(1):1–4
12. Schmidt-Bleek F (2009) The earth: natural resources and human intervention. Haus Publishing, London
13. OECD (2001) Extended producer responsibility: a guidance manual for governments. OECD, Paris